Armed Forces College of Medicine

AFCM

Respiratory System

Gas Exchange

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INTENDED LEARNING OBJECTIVES (ILO)

By the end of this lecture the student will be able to:

1. Define **gas diffusion**.
2. Describe what is the **partial pressure of a gas** (PO_2& PCO_2 in the body).
3. List the **factors affecting gas diffusion** between alveolar air and capillary blood.
4. Describe the **diffusing capacity of a gas**.
5. Compare between **perfusion and diffusion limitations** to gas exchange.

Gas Exchange

- Site:

***At the lungs**

(between pulmonary capillary blood & alveolar air)

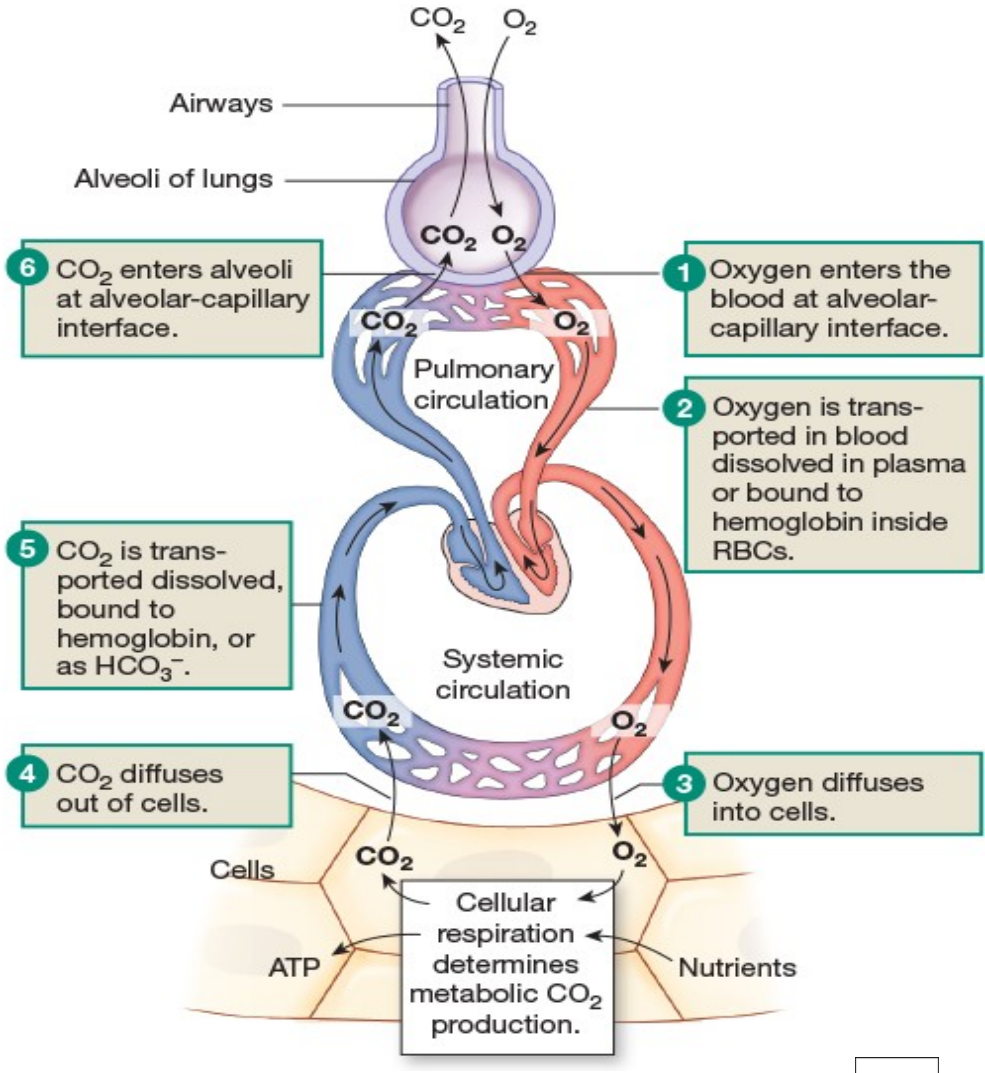
***At the tissues**

(between systemic capillary blood & tissues)

- Mechanism:

Simple Passive Diffusion

down partial pressure gradient (from high to low partial pressure).



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Gas Diffusion

•Definition:

Is a net movement of gas molecules from area of high concentration (high partial pressure) to area of low concentration (low partial pressure).

•Factors affecting:

1- Concentration (partial pressure) gradient of the gas

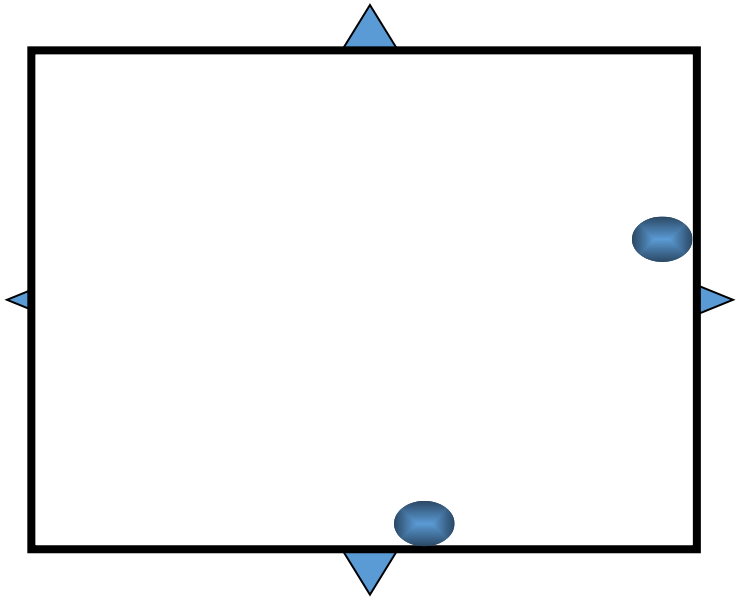
2- Molecular weight of the gas

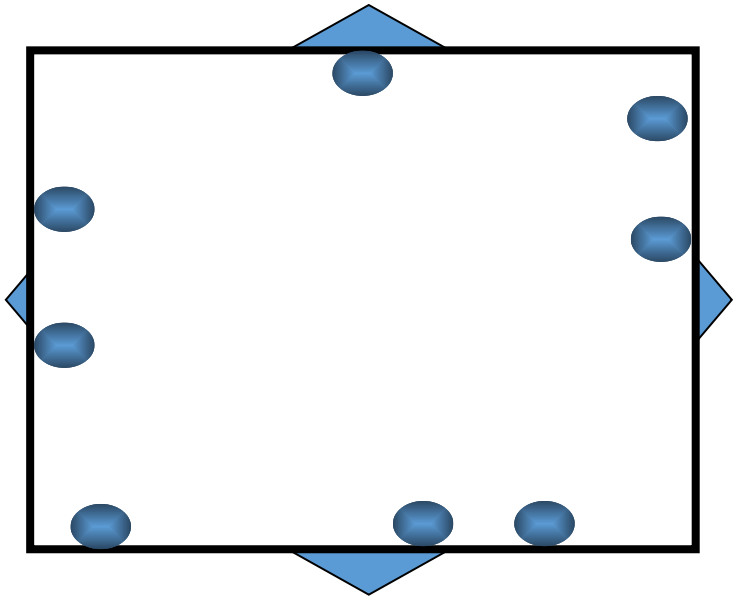
3- Solubility of the gas

4- Temperature

5- Surface area of the membrane

6- Thickness of the membrane





Dalton's Law:

l pressure = Total pressure × Fractional gas concentration

HIGHER PRESSURE

Partial pressure of a gas:

-It is the pressure exerted by this gas when present in a gas mixture.

-It is a measure of gas concentration.

The higher the concentration of dissolved gas, the higher the pressure.

Partial pressure of a gas in blood depends on its physically dissolved form???

Gas exchange at lung level:

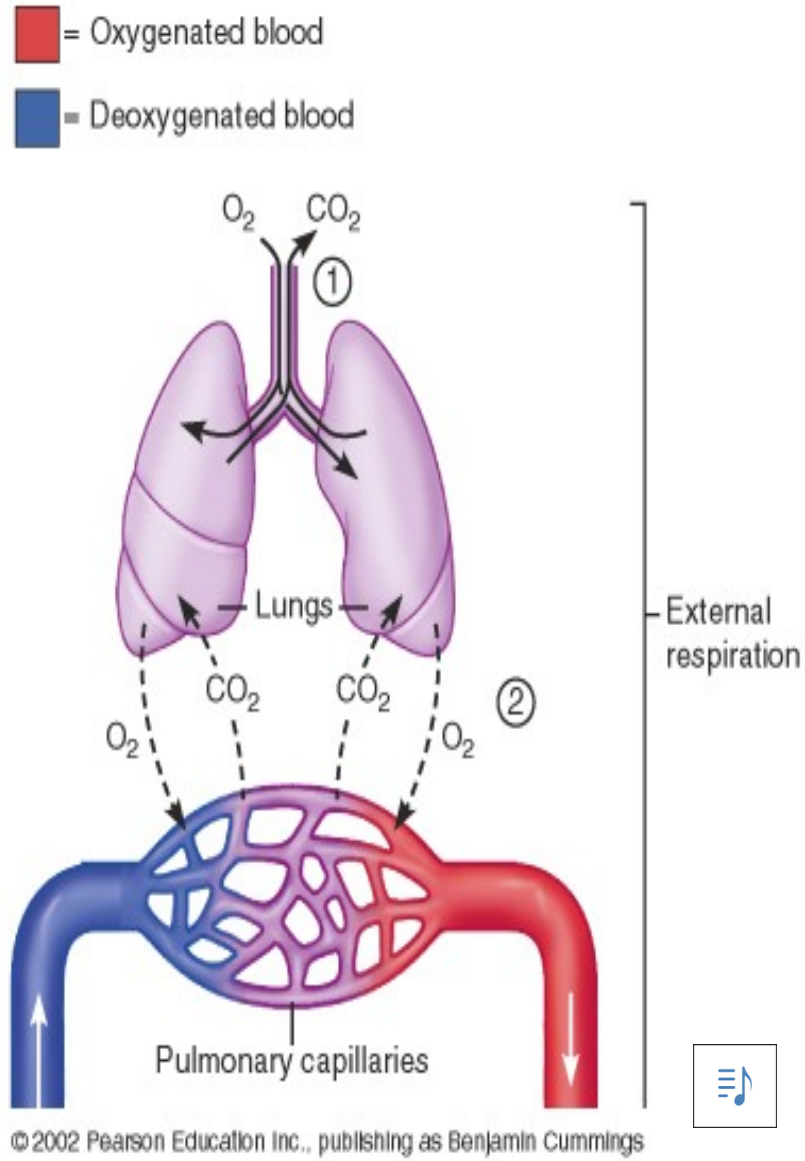
* **Venous blood enters pulmonary capillaries:**

High PCO_2 & Low PO_2

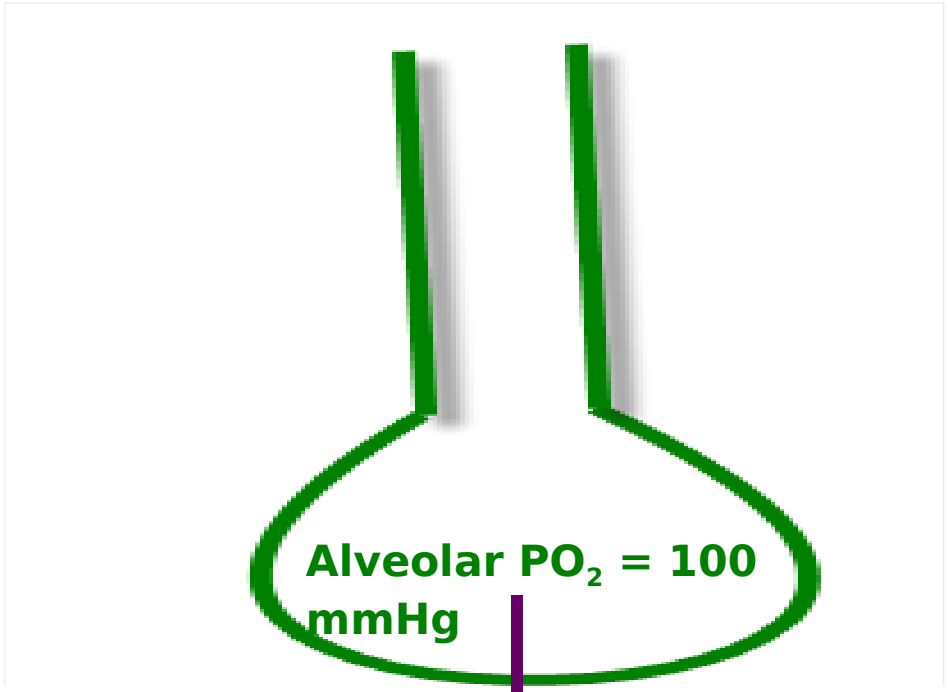
* **Air enters alveoli:**

High PO_2 & Low PCo_2

- ✓ **O_2 diffuses from alveoli to blood down its partial pressure gradient.**
- ✓ **CO_2 diffuses from blood to alveoli down its partial pressure gradient.**



O_2 diffusion



Alveolus

Partial pr. Gradient of 60 mmHg

Pulm. Art. PO_2 = 40 mmHg

(venous blood)

O_2

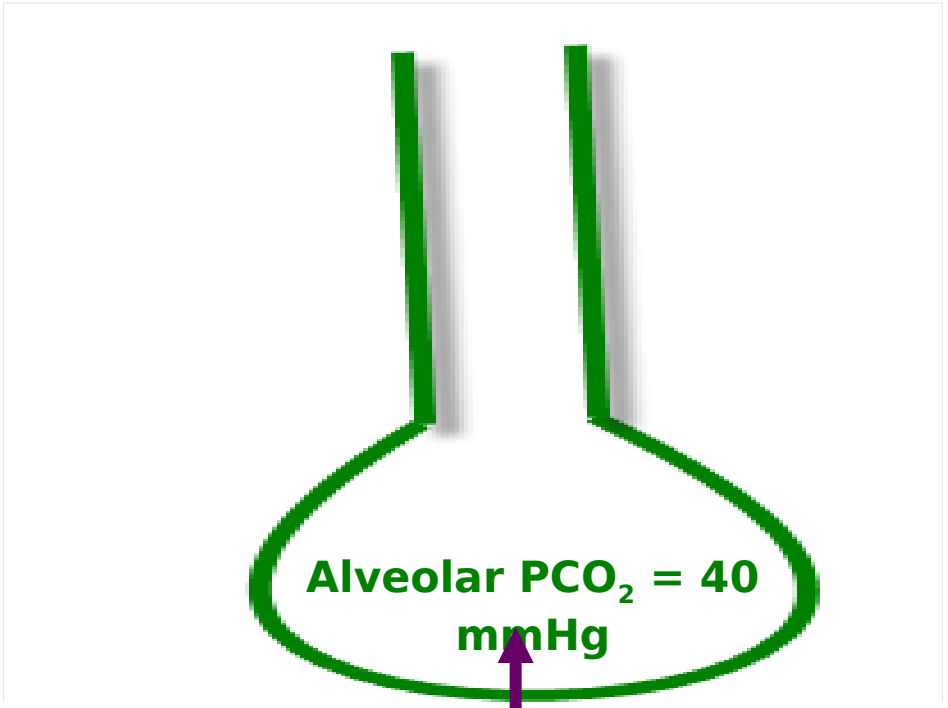
Pulm. Venous PO_2 = 100 mmHg

(arterial blood)

Back to the left atrium

Pulmonary capillary

CO_2 diffusion



Alveolus

Partial pr. Gradient of 6 mmHg

Pulm. Art. PCO_2 = 46 mmHg

(venous blood)

CO_2

Pulm. Venous PCO_2 = 40 mmHg

(arterial blood)

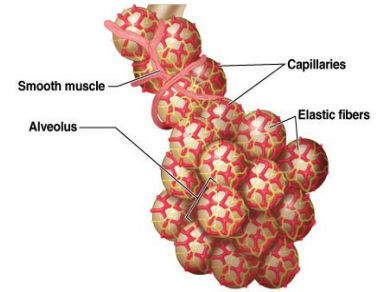
Back to the left atrium

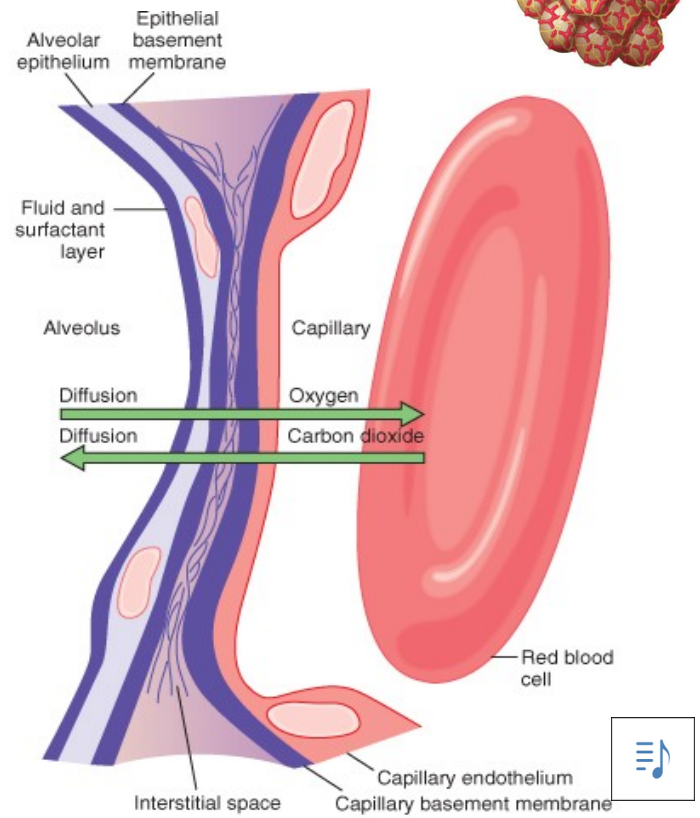
Pulmonary capillary

Alveolar-Capillary membrane (Respiratory membrane)

* In the lung, gas diffusion occurs through the alveolo-capillary membrane:

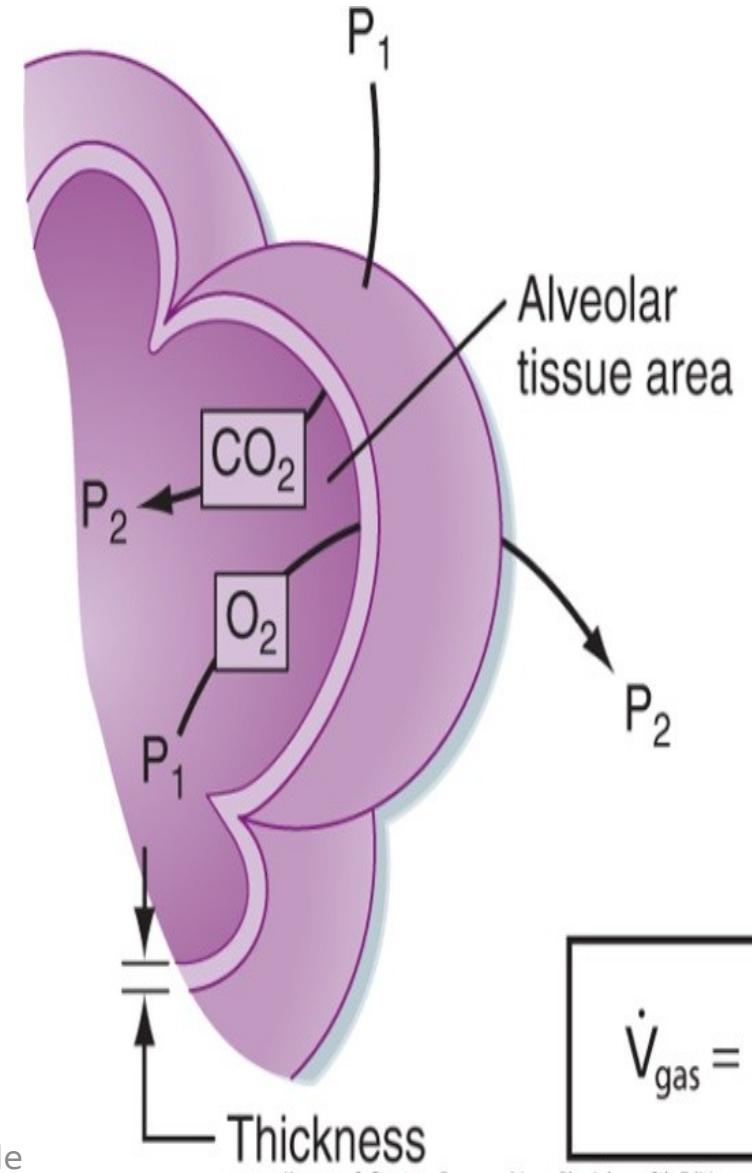
- Thickness: 0.5 to 1 μm.
- Total surface area: 70 m^2
- Formed of the following layers:
  1) Fluid lining alveolus containing surfactant.
  2) Alveolar epithelium.
  3) Epithelial basement membrane.
  4) Interstitial space.
  5) Capillary basement membrane.
  6) Capillary endothelium.





Factors affecting gas diffusion:

- **Gas**
  - P
  - MW
  - Solubility
- **Alveolar-capillary membrane**
  - Surface area
  - Thickness



$$\dot{V}_{gas} = A \times D \times \frac{P_1 - P_2}{T}$$

Koeppen & Stanton: Berne and Levy Physiology, 6th Edition.

Rate of gas diffusion α

Partial Pressure gradient X Surface area of the membrane X Diffusion coefficient

Thickness of the membrane

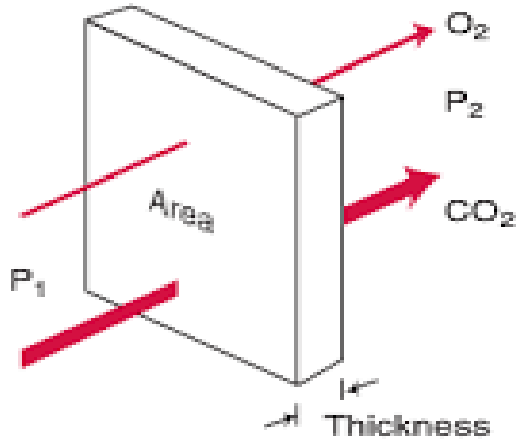
***The volume of gas transfer across the alveolar-capillary membrane per unit time is:

Directly proportional to:

- The difference in the partial pressure of gas betw
- The surface area of the membrane.
- The solubility of the gas.

Inversely proportional to:

- Thickness of the membrane.
- Molecular weight of the gas.



$$\dot{V}_{gas} \propto \frac{A}{T} \cdot D \cdot (P_1 - P_2)$$

$$D \propto \frac{Sol}{\sqrt{MW}}$$

https://www.docsity.com/en/diffusion-capacity-pulmonary-medicine-lecture-slides/

Diffusion coefficient

$$*\text{Diffusion coefficient} \quad \alpha \frac{\text{Solubility of the gas}}{\sqrt{\text{MW of the gas}}}$$

Diffusion coefficient is directly proportional to solubility of the gas, and inversely proportional to the square root of gas's molecular weight (MW).

- **Diffusion coefficient for CO_2 is 20 times that of O_2;**

CO_2 is 24 times more soluble than O_2 is, but the MW of CO_2 is 1.4 times greater than that of O_2.

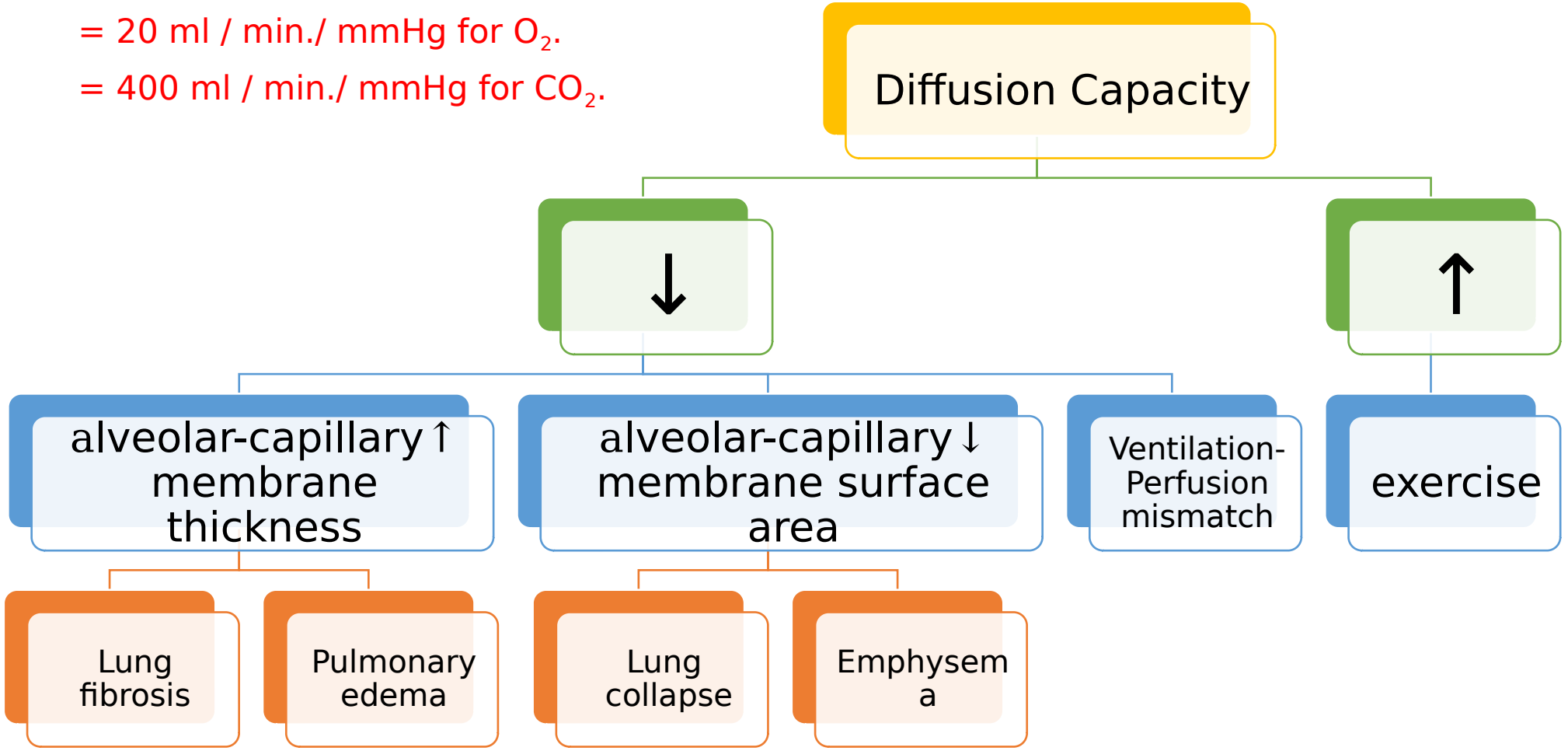
- In lung diseases that impairs diffusion, **O_2 diffusion** is **more seriously impaired** than CO_2 diffusion because of the greater CO_2 diffusion coefficient.

The diffusion capacity of the respiratory membrane

- **Definition:** The volume of gas that diffuses across the alveolar-capillary membrane / min for a pressure difference of 1 mmHg.

= 20 ml / min./ mmHg for O_2.

= 400 ml / min./ mmHg for CO_2.



Types of Gas Exchange:

Diffusion-Limited Gas Exchange

applies to CO

Perfusion-Limited Gas Exchange

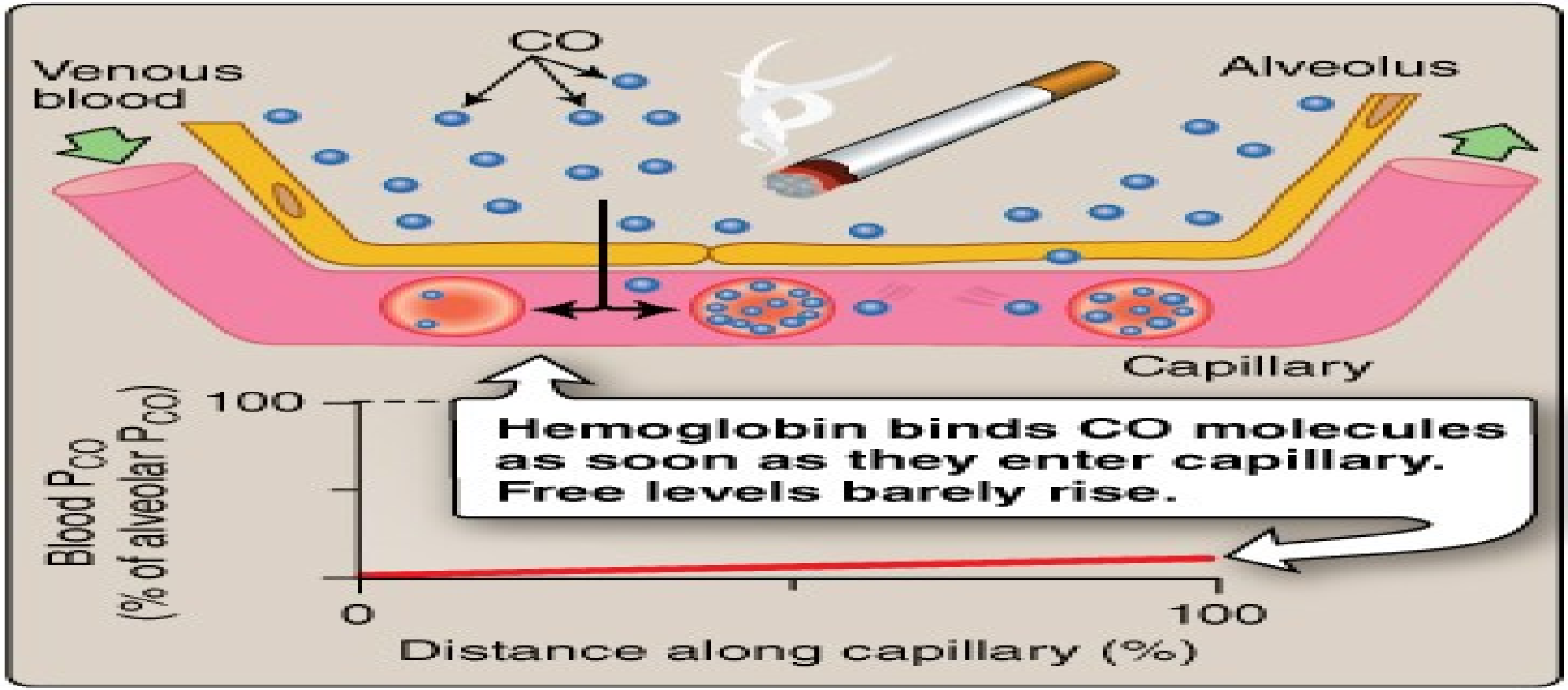
applies to N_2O

Types of Gas Exchange:

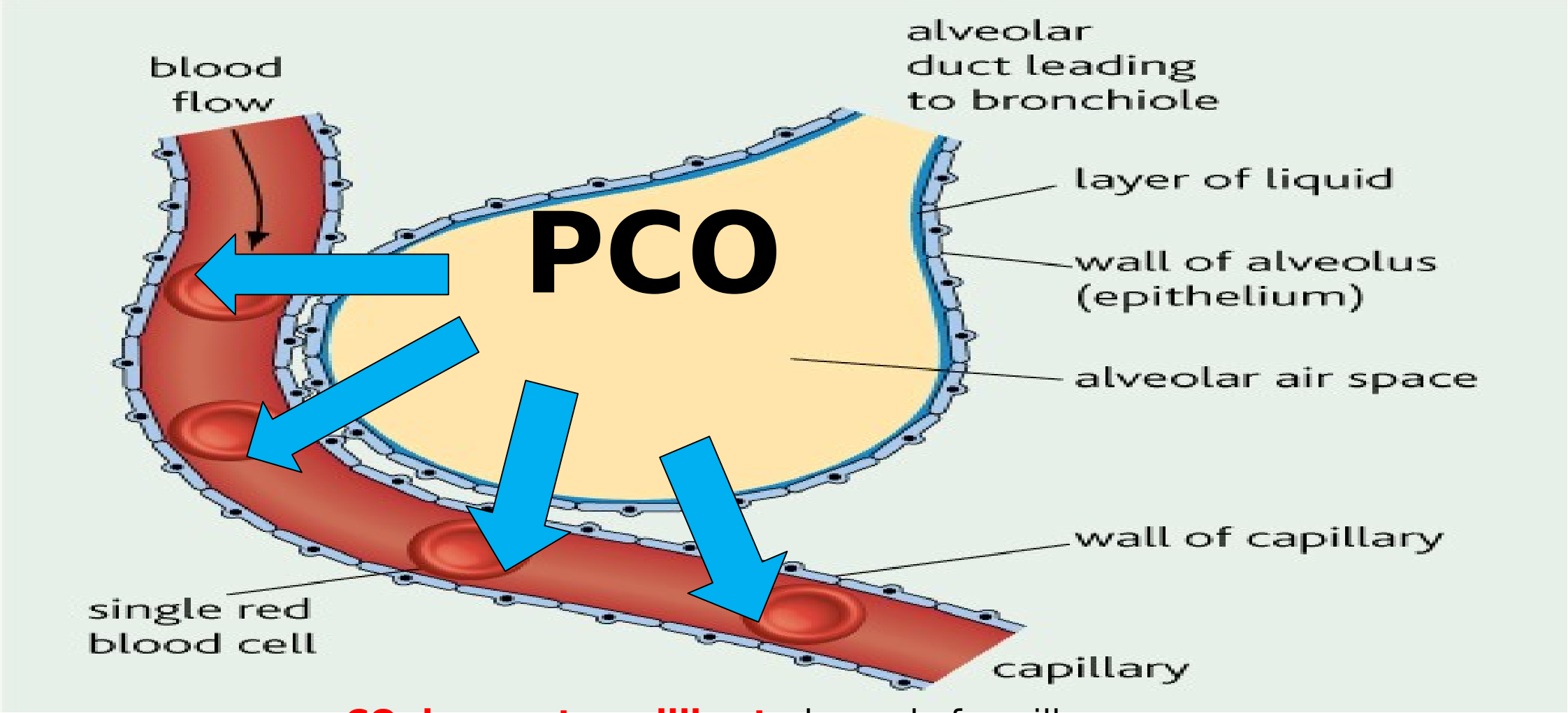
N.B:

- The physically dissolved form of the gas is the form that determine its partial pressure.
- Net diffusion into pulmonary capillary depends on magnitude of partial pressure gradient.
- **Whether a gas reaching equilibrium or not depends on its reaction with substances in the blood.**
- **0.75 sec is the time the blood takes to traverse the pulmonary capillaries at rest.**

Diffusion-Limited Gas Exchange (CO)



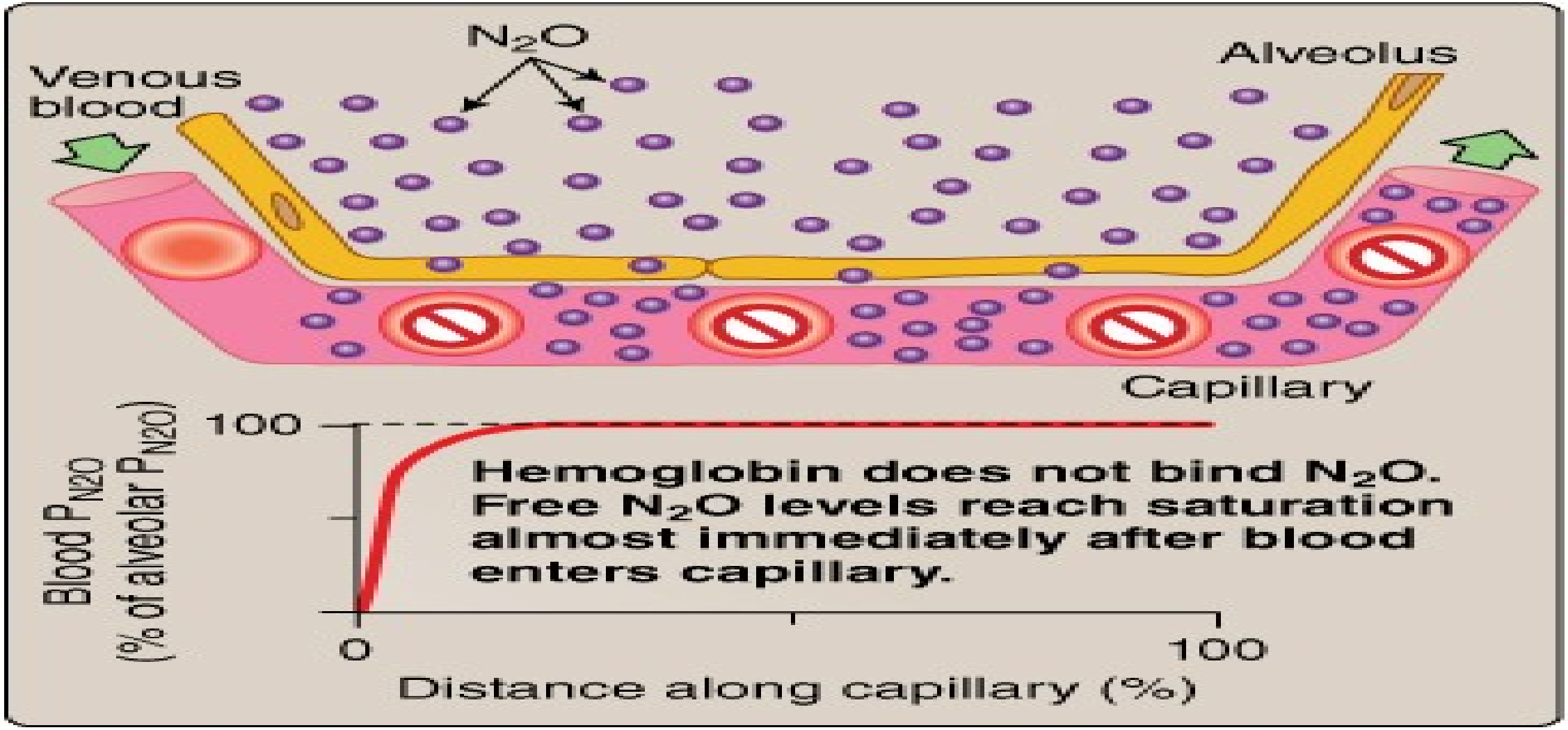
Diffusion-Limited Gas Exchange (CO)



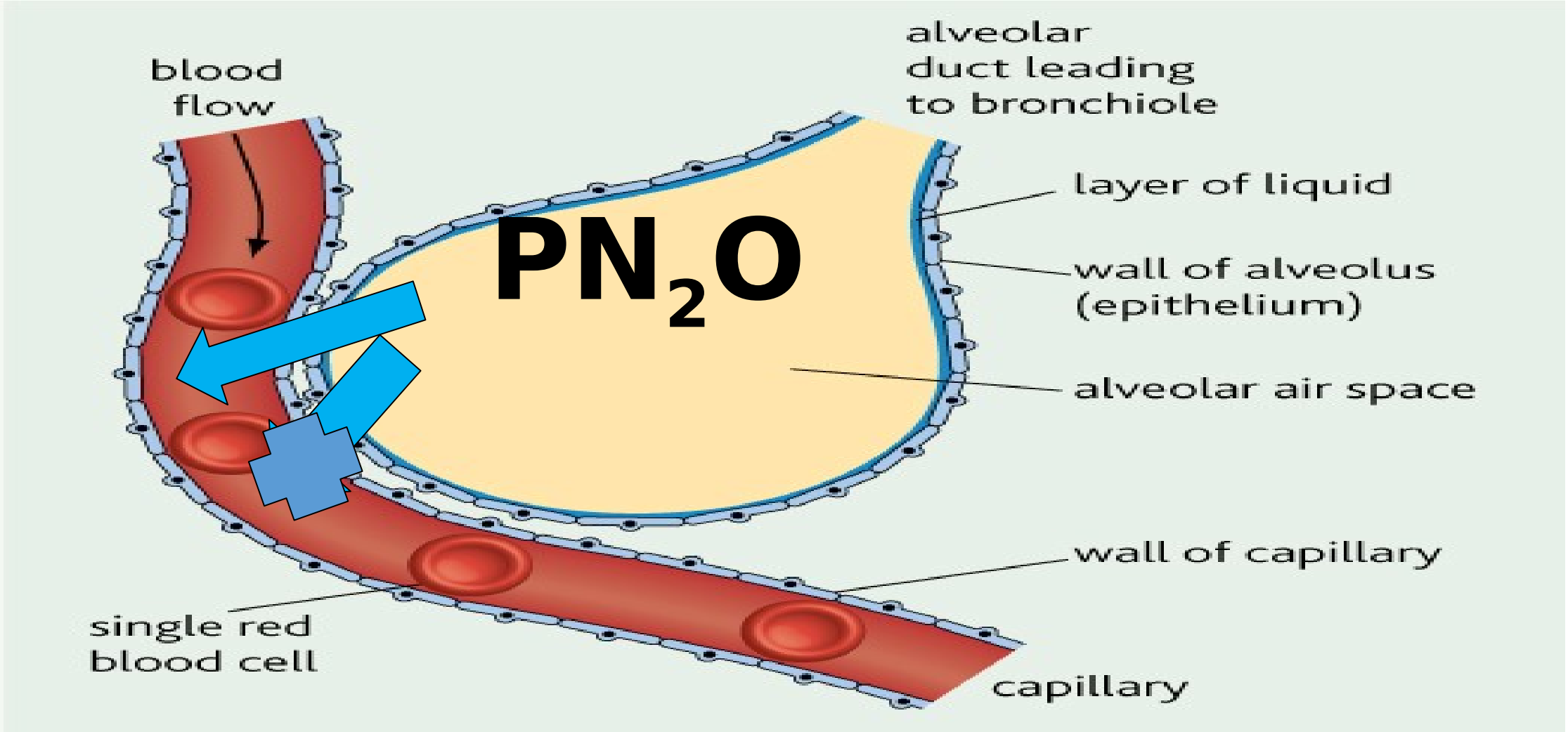
CO does not equilibrate by end of capillary

https://y12hb.wordpress.com/2013/04/07/the-lungs/

Perfusion-Limited Gas Exchange (N_2O)



Perfusion-Limited Gas Exchange (N_2O)



N_2O equilibrates early along length of capillary reaches equilibrium in about 0.1 s

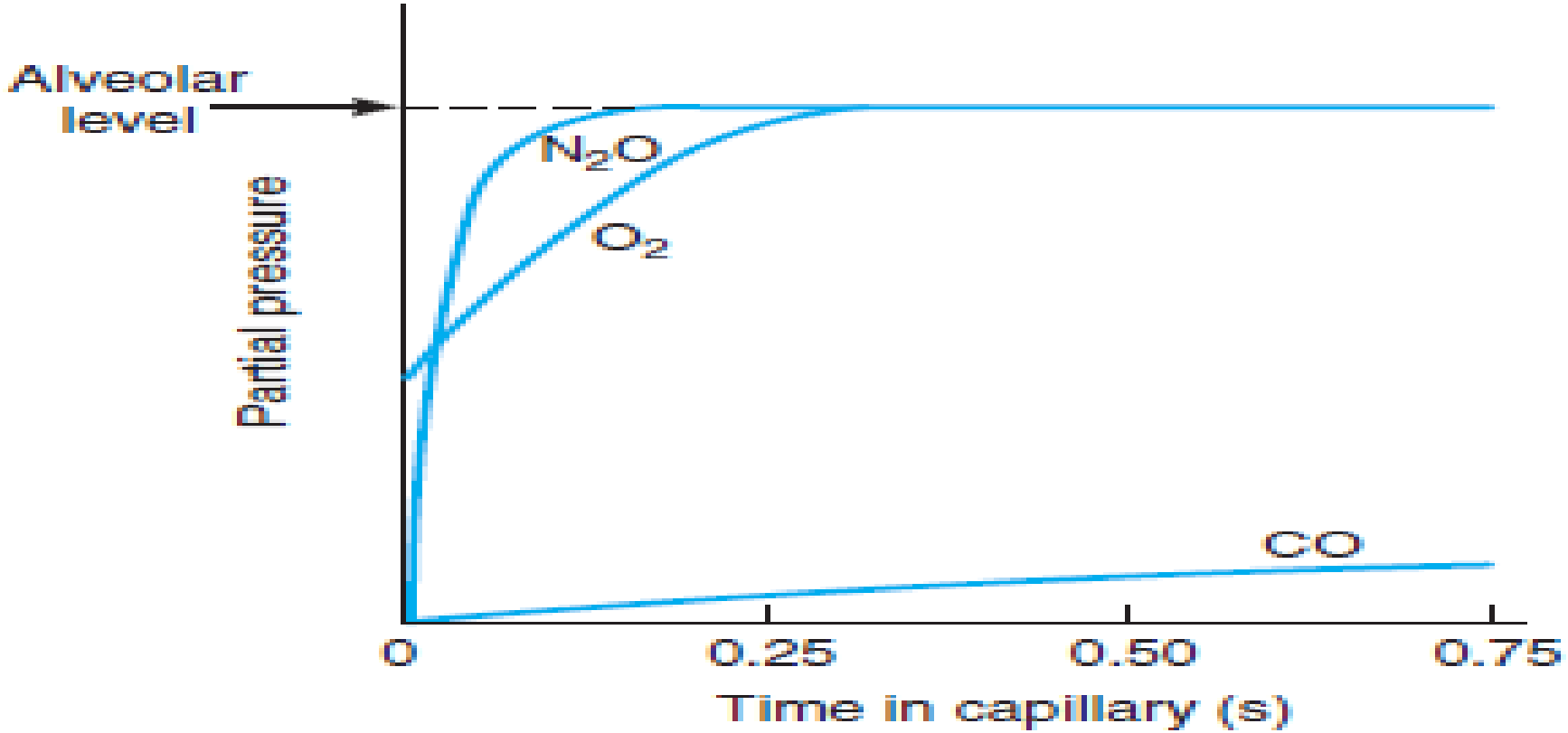
https://y12hb.wordpress.com/2013/04/07/the-lungs/

Gas Exchange (O_2)

O_2 is intermediate between N_2O and CO; it is taken up by hemoglobin, but much less avidly than CO, and it reaches equilibrium with capillary blood in about 0.3 sec.

Thus, its uptake is **perfusion-limited.**

Gas Exchange (CO, N_2O, O_2)



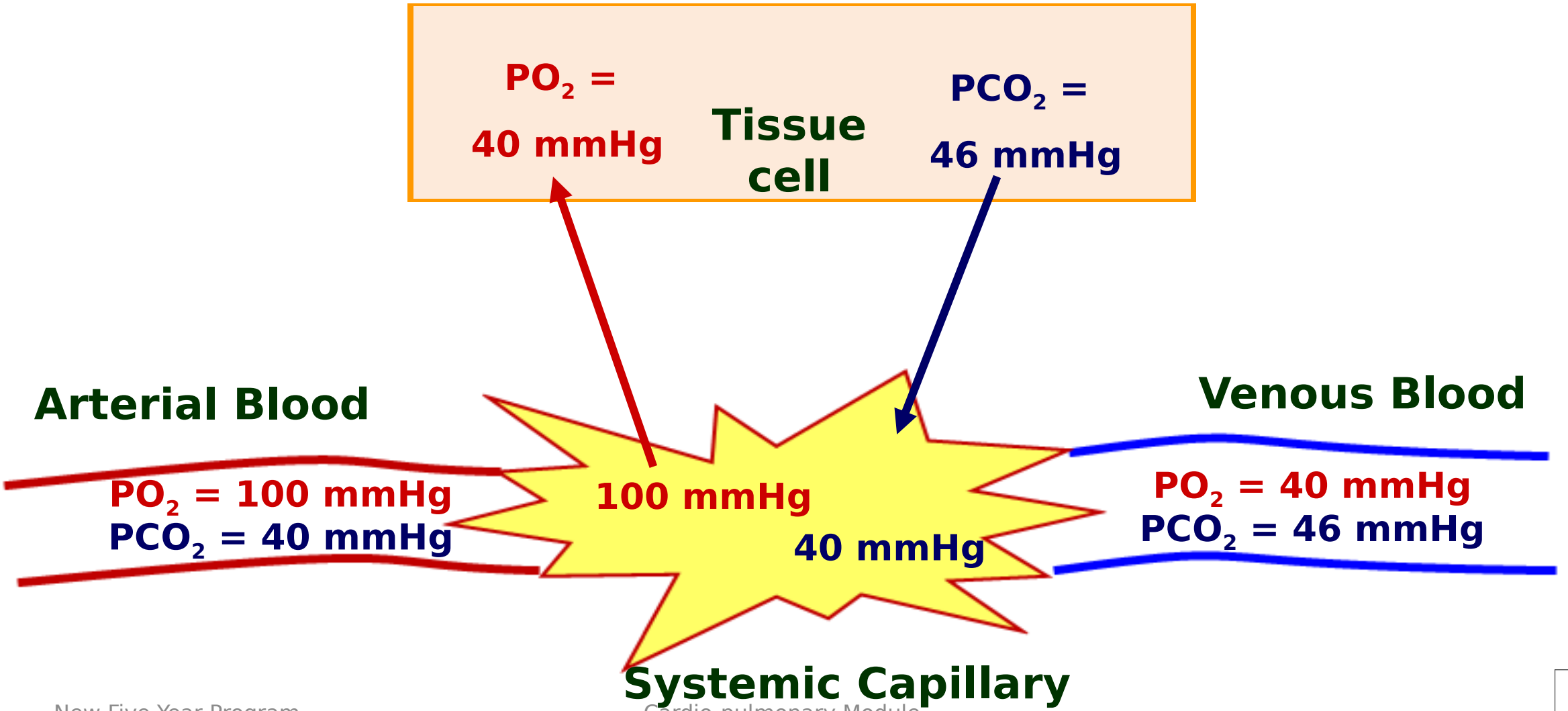
-N_2O is not bound in blood, so its partial pressure in blood rises rapidly to its partial pressure in the alveoli.

-Conversely, CO is avidly taken up by red blood cells, so its partial pressure reaches only a fraction of its partial pressure in the alveoli.

-O_2 is intermediate between the two.

Ganong 25th ed.

Gas Exchange At Tissue Level



Lecture Quiz

1. Define *partial pressure of gas.*
2. What determines the partial pressures of a gas?
3. Make a sketch showing the PO_2 and PCO_2 gradients and the direction of O_2 and CO_2 movement between the alveoli and pulmonary capillaries and between the tissue cells and systemic capillaries.

SUGGESTED TEXTBOOKS

1. **Ganong’s review of medical physiology 25th edition**
2. **Lippincott’s illustrated reviews: Physiology**
3. **BRS Physiology 6th ed.**